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Self-Aware Computing: A Primer

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Abstract— The term self-awareness has been adopted from biology and cognitive science. It refers to the capability of a system to obtain and react upon certain knowledge. It has been proposed as a means for advance autonomous adaptive behavior for complex systems. Self-aware computing is a paradigm for structuring and simplifying the design and operation of complex, dynamic computing systems. This paper provides a brief introduction to self-aware computing.

Keywords— self-aware computing, autonomic computing, organic computing

I. INTRODUCTION

Computing systems are becoming increasingly complex, heterogeneous, dynamic, and decentralized. Since humans can no longer deal with the rising complexity (which may include scale, uncertainty, and heterogeneity) of the systems, these systems should be enabled to autonomically manage themselves. One approach on how to rise to this challenge is to endow computing systems with increased self-awareness, in order to enable autonomous adaptive behavior.

In order to effectively manage itself, a system needs knowledge about itself and its environment. Self-awareness is concerned about availability, collection and representation of knowledge about a system, by that system, and the ways that system can update that knowledge. This knowledge helps in reasoning and smart decision making for adaptive behavior [1].

Self-awareness is a well-studied concept in the fields of psychology and cognitive science.

Many experiments have shown that self-focused attention has important implications for self-regulation and self-evaluation to occur. Self-awareness is a key attribute in both autonomic and organic computing. The need for self-awareness has arisen in a variety of areas of computer science and engineering in recent years. Advanced organisms also engage in meta-self-awareness, which is a higher level of self-awareness, i.e. an awareness that they themselves are self-aware [2]. For example, meta-self-awareness is needed in selecting between different sensors, actors, learning techniques or between multiple adaptation strategies.

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II. LEVELS OF SELF-AWARENESS

There are different levels of self-awareness, ranging from basic awareness of environmental stimuli to awareness of one's own thoughts [3, 4]. These are illustrated in Figure 1 [1] and explained as follows.

1. *Stimulus-aware:* A node is stimulus-aware if it has knowledge of stimuli. Stimulus-awarenessis a prerequisite for all other levels of self-awareness. Since stimuli may originate both internally and externally, stimulus-awareness can either be private, public or both. Private self-awareness refers to a node possessing knowledge of phenomena that are internal to itself. Public self-awareness concerns with a node possessing knowledge of phenomena external to itself.
2. *Interaction-aware:* A node is interaction-aware if it has knowledge that stimuli and its own actions form part of interactions with other nodes and the environment. Through feedback loops, the interaction-aware system can learn that its actions can cause specific reactions from its social or physical environments.
3. *Time-aware:* A node is time-aware if it has knowledge or information about history, experience, or likely future phenomena. Implementing time awareness might require having the system use explicit memory.
4. *Goal-aware:* A node is goal-aware if it has knowledge of current goals, objectives, preferences, and constraints. Goal-awareness permits changes in goals, which can be eitherlocal or global goals. Self-aware systems work under constraints of user goals.
5. *Meta-self-aware:* A node is meta-self-aware if it has knowledge of its own level(s) of awareness. A meta– self-aware system can adapt the way in which it realizes a self- awareness level.

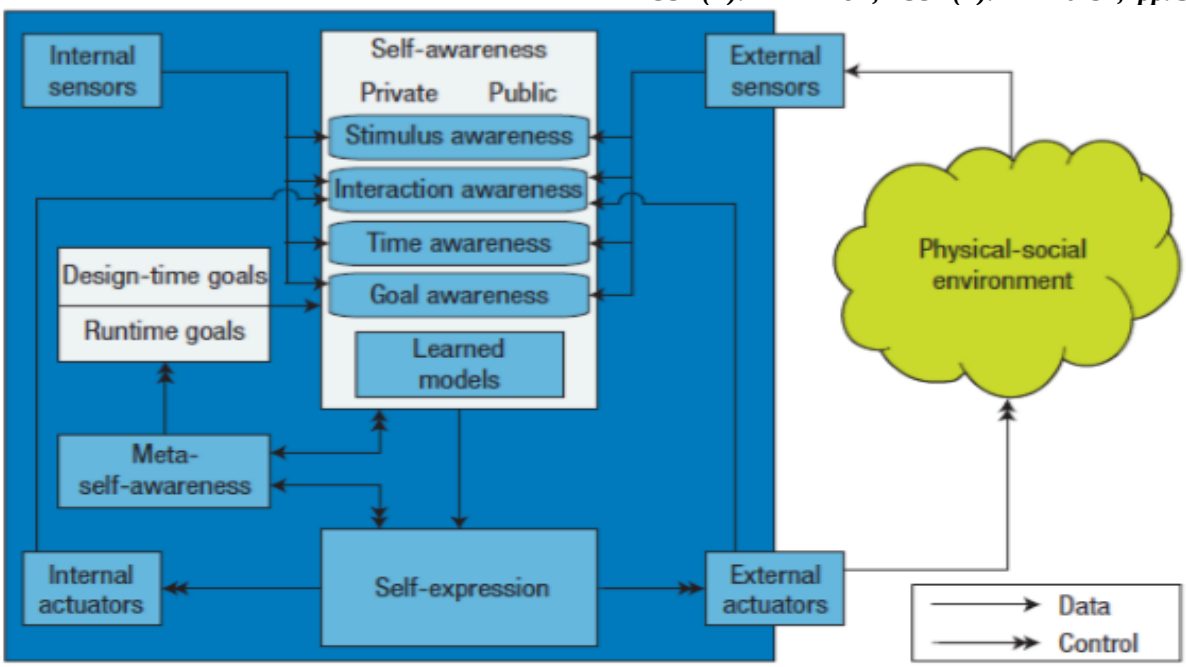

Figure 1 Different self-awareness levels [1].

III. CONCEPT OF SELF-AWARE COMPUTING

Self-aware computing systems are essentially a subclass of autonomic computing systems. They are computing systems thatmodels capturing knowledge about themselves and their environment on an ongoing basis. They are systems that are inspired by self-awareness concepts in humans and animals. They automatically adjust their behavior in response to environment stimuli to meet user specified goals [5]. They can collect information both from internal sensors and external sensors. A comparison between traditional system and self-aware system is made in Figure 2 [6].

A self-aware computer is capable of achieving 10x to 100x improvement in key metrics such as power efficiency and cost performance over extant computers. **S**elf-aware computing is related to autonomic computing and organic computing. In the autonomic computing system, end-users define high-level goals and the system adapts to achieve the desired behavior. The system can alter its behavior to meet multiple goals and automatically adapt to environmental changes.A self-aware system has knowledge and experiences of itself, allowing reasoning and intelligent decision making to support effective, autonomous adaptive behavior.

The design of self-aware computing systems requires an integrated interdisciplinary approach from multiple areas of computer science and engineering, including software and systems engineering, systems modeling, simulation and analysis, autonomic and organic computing, machine learning and artificial intelligence, data center resource management, etc. How some of these areas are related to self-aware system as illustrated in Figure 3 [7].

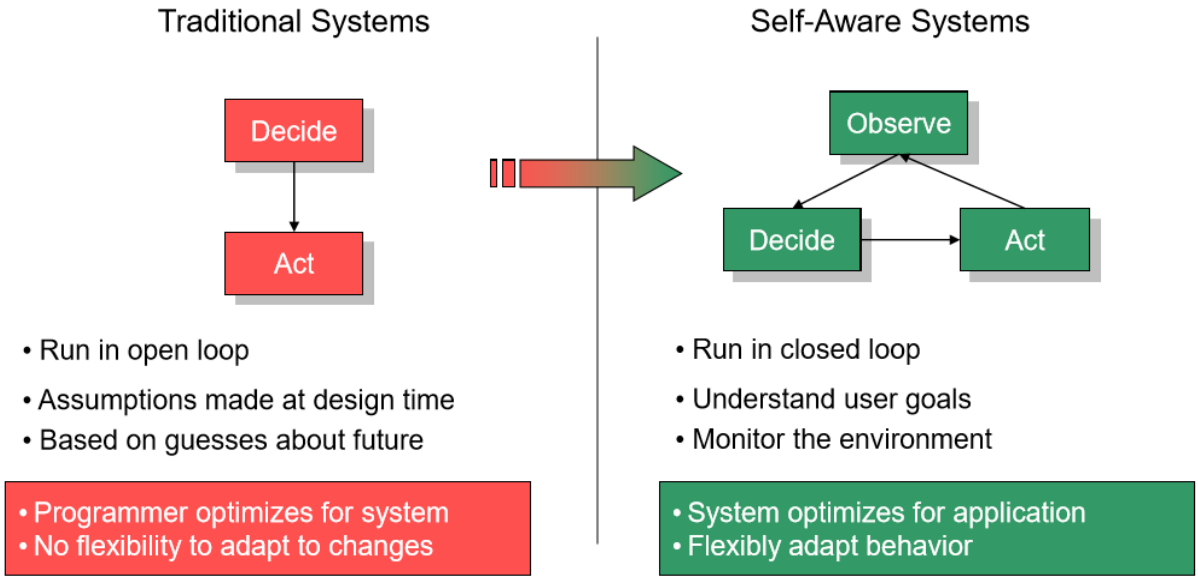

Figure 2 Comparison between traditional and self-aware systems [6].

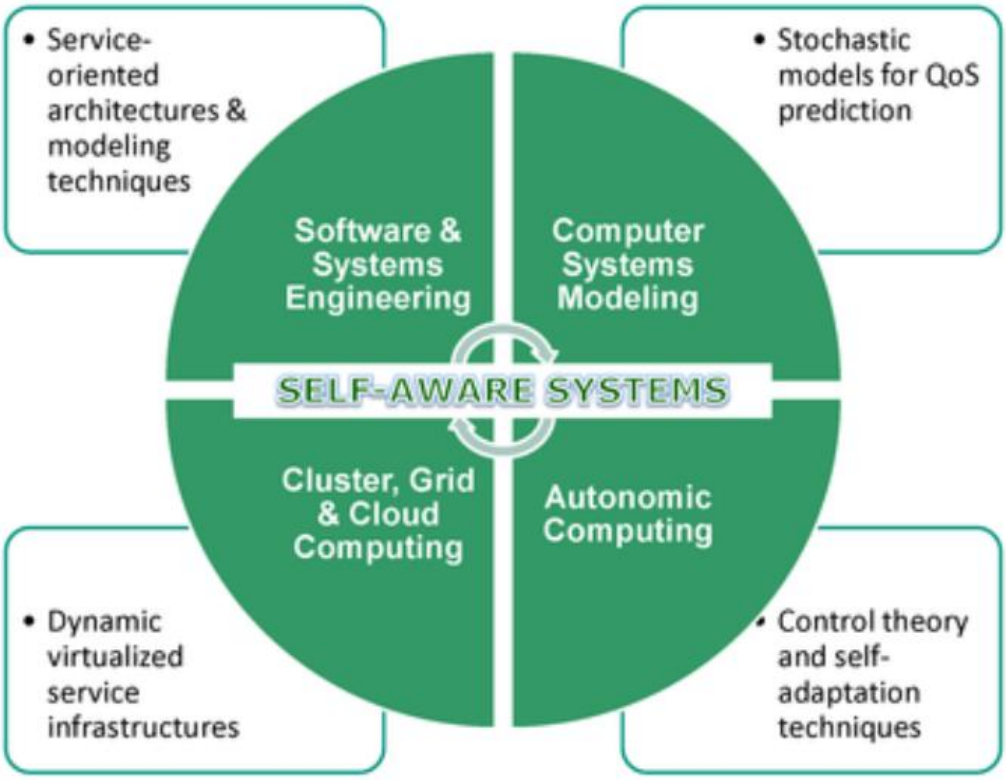

Figure 3 How self-aware computing is related to areas of computer science and engineering [7].

IV. APPLICATIONS

Applications of self-aware computing include autonomic computing, organic computing, control systems, automation, robots, and military. In some of these applications, self-awareness is essential for safety and ethics.

- *DARPA System:* The military is interested in self-aware computing systems that could help soldiers or pilots, for example, on hazardous missions. The systems will automatically study a situation, determine potential actions, and calculate the best alternative. Police officers and firefighters could also benefit from such systems, which are being managed by the US Defense Advanced Research Projects Agency (DARPA) [8].
- *Self-aware Computing Framework* (SEEC): SEEC addresses the problem of automatically and dynamically scheduling actions while balancing competing goals in a fluctuating environment. Itautomatically and dynamically schedules actions to meet application specified goals. It is designed to incorporate observations made at both the system and application level [9].
- *Automation:* The IT industry badly needs automation technologies to help deal with some challenges. Automation helps reduce manual labor cost in management and administration. There have been an increasing number of companies that aim at developing automation solutions for capacity planning, provisioning and deployment, service level assurance, anomaly detection, failure/performance diagnosis, high availability, disaster recovery, and security enforcement [10].

V. CONCLUSION

In order to cope with evolving environment and changing user needs, a system should have knowledge about itself and its surroundings. Our concept of computational self-awareness can provide computing systems with autonomous behavior in rapidly changing conditions. Self-aware computing systems are designed to address a growing need for automation in the management of large, complex computer applications. For more information on self-aware computing, one should consult the books in [3, 11, 12].

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